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EXPERIMENTS IN DEVELOPING GREEN FLARE FORMULAS

Carl Armour

U. S. NAVAL AMMUNITION DEPOT
CRANE, INDIANA

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Director, Research & Development Department

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ABSTRACT

The Chemical Laboratory Branch was given the task of developing improved colored flares, which would burn longer than the formula currently in use.

Eighty green flare producing formulas were mixed and tested for burning time and quality of flame. Burning temperatures measured on twelve formulas containing barium indicate that an energy level associated with a temperature ranging from approximately 1100°C to 1355°C is required to produce a green color, with the more intense colors being produced at approximately 1300°C. Below the above minimum temperature the flames were yellow, above the maximum the colors approached white light.

The most promising formulas developed consisted of an efficient three component system containing boron, barium nitrate and polyvinyl chloride.

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Introduction

Most of the green flare formulas consist of systems containing 5 to 7 ingredients and are comparatively short burners. The task was undertaken to develop more efficient colored flares with longer burning times. It was hoped to incorporate color into the long burning phosphorus composition.

I. Procedure and Test Results

The formulas were mixed in the laboratory under the hood in approximately ten gram batches. Nine and eight tenths grams of the flare compositions were loosely poured into steel tubes 3/4" x 4", stoppered at one end with corks. The ignition composition consisted of .5 gram of 6-6-8 starter mix poured on top of the flare composition. The ignition was secured by means of lighting an 8 inch piece of fire cracker fuse stuck in the starter mix. The burning time was taken with a stop watch and the color evaluation was based on visual inspection. The formulas were rated as poor, fair, good and very good.

II. Eighty flare formulas were mixed and tested with the results as listed below:

Formula No. 1	Pts.	B.T.	Degree of Green Color
Magnesium	1.8	5.8	Good
$Ba(NO_3)_2$	5.8		
Hexachlorbenzene	1.2		
Cu	.5		
Parlon	.3		
Gilsonite	.2		
Formula No. 2			
Magnesium	1.8	10.2	Very Good
Barium Nitrate	5.8	11.6	Very Good
Cu	.5	10.2	Very Good
Parlon	1.5	11.6	Very Good
Gilsonite	.2		
Formula No. 3			
Magnesium	.9	15	Poor, Yellow flame with tinge of green
Barium Nitrate	5.8		
Copper Dust	.5		
Parlon	1.9		
Shellac	.5		
Gilsonite	.2		

	Pts.	B.T.	Degree of Green Color
Formula No. 4			
Magnesium	.9	16	Good
Barium Nitrate	5.8		
Copper Dust	.5		
Parlon	2.4		
Gilsonite	.2		
Formula No. 5			
Magnesium	1.0	15	Good
Barium Nitrate	5.8		
Copper Dust	1.3		
Parlon	1.5		
Gilsonite	.2		
Formula No. 6			
Magnesium	1.0	8.3	Very Good
Barium Nitrate	5.8		
Copper	1.3		
Parlon	1.7		
Formula No. 7			
Magnesium	1.8	9.2	Very Good
Barium Nitrate	5.8		
Copper	.5		
Parlon	1.7		
Formula No. 8			
Magnesium	1.0	9.3	Good
Barium Nitrate	4.8		
Copper	1.3		
Parlon	1.7		
Formula No. 9			
Magnesium	1.0	10.2	Good
Barium Nitrate	4.8		
Copper	2.3		
Parlon	1.5		
Gilsonite	.2		
Formula No. 10			
Magnesium	1.0	17.5	Yellow tinged with Green
Barium Nitrate	4.8		
Copper	1.3		
Parlon	2.7		

Formula No. 11

	Pts.	B.T.	Degree of Green Color
Magnesium	1.0	12	Fair
Barium Nitrate	4.8		
Copper	1.3		
Parlon	1.7		
Hexachlorbenzene	1.0		

Formula No. 12

Magnesium	1.0	14.9	Poor
Barium Nitrate	4.8		
Copper	1.3		
Parlon	1.7		
Mercuric Chloride	.1		

Formula No. 13

Magnesium	1.8	7.5	Very Good
Barium Nitrate	5.8		
Parlon	2.0		
Gilsonite	.2		

Formula No. 14

Wood Flour	1.8	49.3	Yellow tinged with Green
Barium Nitrate	5.8		
Parlon	1.5		
Gilsonite	.2		
Copper	.5		

Formula No. 15

Wood Flour	1.3	105	Yellow
Barium Nitrate	5.8		
Parlon	2.0		
Gilsonite	.7		

Formula No. 16

Magnesium	1.0	12.8	Poor
Barium Nitrate	5.8		
Parlon	2.0		
Gilsonite	1.0		

Formula No. 17

Magnesium	.5	40.8	Yellow tinged with Green
Wood Flour	1.3		
Barium Nitrate	5.8		
Parlon	2.0		
Gilsonite	.2		

Formula No. 18

	Pts.	B.T.	Degree of Green Color
Magnesium	1.8	15	Good
Barium Nitrate	5.8	9	Very good, substituted Mag.Gran 15 for 80/120 Mag.
Polyvinyl Chloride	2.0	13	Very good
Gilsonite	.2		

Formula No. 19

Charcoal	1.8	72.6	Yellow with a slight tinge of green
Barium Nitrate	5.8		
Parlon	1.5		
Gilsonite	.2		
Copper	.5		

Formula No. 20

Charcoal	1.8	44.4	Yellow tinged with Green
Barium Nitrate	5.8		
Parlon	1.5		
Gilsonite	.2		
Magnesium	.5		

Formula No. 21

Charcoal	1.8	35.8	Yellow tinged with Green
Barium Nitrate	5.8		
Parlon	1.5		
Magnesium	.7		

Formula No. 22

Magnesium	1.3	17.2	Yellow with a Green tinge
Barium Nitrate	5.8		
Polyvinyl Chloride	2.0		
Gilsonite	.7		

Formula No. 23

Magnesium 30/50	1.8	17.2	Fair
Barium Nitrate	5.8	12.2	Good
Polyvinyl Chloride	2.0		
Gilsonite	.2		

Formula No. 24

Magnesium	1.5	21.8	Good
Barium Nitrate	5.8		
Polyvinyl Chloride	2.6		
Gilsonite	.2		

Formula No. 25	Pts.	B.T.	Degree of Green Color
Magnesium	1.5	18.2	Good
Barium Nitrate	5.8		
Polyvinyl Chloride	2.3		
Gilsonite	.2		
Formula No. 26			
Magnesium	1.8	8.8	Very Good
Barium Nitrate	5.8		
Hexachlorethane	2.0		
Gilsonite	.2		
Formula No. 27			
Magnesium	1.5	13	Very Good
Barium Nitrate	5.8		
Hexachlorethane	2.3		
Gilsonite	.2		
Formula No. 28			
Magnesium	1.8	17.2	Very Good
Barium Nitrate	5.8	12.2	Very Good
Polyvinyl Chloride	2.2		
Formula No. 29			
Magnesium	1.8	12.2	Very good - more brilliant than No. 28
Barium Nitrate	5.8		
Parlon	2.2		
Formula No. 30			
Magnesium	1.8	12.2	Very good but not as good as No. 28 or 29
Barium Nitrate	5.8		
Hexachlorethane	2.2		
Formula No. 31			
Magnesium	1.3	18.2	Yellow tinted with Green
Barium Nitrate	5.8		
Polyvinyl Chloride	2.7		
Formula No. 32			
Magnesium	1.3	9.5	Very good
Barium Nitrate	5.8		
Parlon	2.7		

	Pts.	B.T.	Degree of Green Color
Formula No. 33			
Magnesium	1.0	10.5	Good
Barium Nitrate	5.8		
Polyvinyl Chloride	3.0		
Formula No. 34			
Magnesium	1.3	16.5	Good
Barium Nitrate	5.8		
Polyvinyl Chloride	2.7		
Formula No. 35			
Magnesium	1.0	22	Yellow with Green color about last 10 sec. as heat built up
Barium Nitrate	5.8		
Polyvinyl Chloride	3.0		
Formula No. 36			
Magnesium	1.8	11	White Light tinged with Green. Tube was red hot.
Barium Nitrate	5.8		
Hexachlorbenzene	2.2		
Formula No. 37			
Magnesium	1.5	13.5	Poor
Barium Nitrate	5.8	19.0	Fair
Polyvinyl Chloride	2.5		
Formula No. 38			
Charcoal	1.5	75	Yellow with a faint tinge of Green.
Barium Nitrate	5.8		
Polyvinyl Chloride	1.5		
Magnesium	.5		
Formula No. 39			
Charcoal	1.0	46	Yellow tinged with Green, with Green being more intense as energy level increased.
Barium Nitrate	5.8		
Polyvinyl Chloride	2.0		
Magnesium	1.0		

Formula No. 40

	Pts.	B.T.	Degree of Green Color
Charcoal	.5	24.2	Fair
Barium Nitrate	5.8		
Polyvinyl Chloride	2.0		
Magnesium	1.5		

Formula No. 41

Magnesium	1.0	12	Poor
Dextrine	.8		
Barium Nitrate	5.8		
Polyvinyl Chloride	2.2		

Formula No. 42

Magnesium	1.8)	48	Burned with a Yellow flame for approximately 35 seconds then with a good Green for 10 seconds
Barium Nitrate	5.8)		
Copper	.5)4 pts.		
Parlon	1.7)		
Stafoam plastic formulation 6.6 pts.			

Formula No. 43

Magnesium	2.3)	Dud	The composition foamed out of tube, was pushed down and an attempt made to ignite.
Barium Nitrate	5.8)4 pts.		
Parlon	1.7)		
Stafoam	6.6 pts.		

Formula No. 44

Magnesium	1.6	6.5	Used 80/120 Magnesium Poor
Barium Nitrate	3.3		
Potassium Perchlorate	2.3	10.5	Used magnesium type III granulation 15
Neofat (stearic acid)	.7		
Polyvinyl Chloride	1.7		Good
		16.8	Used magnesium type III granulation 15 Good
		13.8	Very Good - used magnesium type III granulation 16

Formula No. 45

Magnesium	1.8	22	Yellow tinged with Green
Barium Nitrate	4.8		
Polyvinyl Chloride	3.2		

Formula No. 46

	Pts.	B.T.	Degree of Green Color
Magnesium	1.0	30.5	Yellow changing to Green as energy level mounted.
Gilsonite	1.0		
Barium Nitrate	5.8		
Polyvinyl Chloride	2.0		

Formula No.47

Magnesium	2.0	9.2	Very Good - used magnesium type III granulation 15
Barium Nitrate	5.8		
Polyvinyl Chloride	2.0		

Formula No. 48

Magnesium	1.8	18.8	White light with tinge of Green
Barium Nitrate	5.3		
Polyvinyl Chloride	2.7		

Formula No. 49

Magnesium	1.0	16.0	White light
Gilsonite	1.0		
Barium Nitrate	5.8		
Hexachloroethane	2.0		

Formula No. 50

Magnesium	1.5	22.6	Good
Gilsonite	.5	17.2	Good
Barium Nitrate	5.8		
Polyvinyl Chloride	2.0		

Formula No. 51

Magnesium	1.5	15.2	Good
Gilsonite	.3		
Barium Nitrate	5.8		
Polyvinyl Chloride	2.2		

Formula No. 52

Magnesium	1.8)		
Barium Nitrate	5.8)	10 pts.	Dud
Polyvinyl Chloride	2.2)		
Laminac		5 pts.	

Formula No. 53

	Pts.	B.T.	Degree of Green Color
Magnesium	1.8	20.5	Good
Barium Nitrate	5.6		
Mercuric Chloride	.2		
Polyvinyl Chloride	2.2		

Formula No. 54

Magnesium	2.4	11	Very Good
Barium Nitrate	5.8		
Polyvinyl Chloride	1.6		

Formula No. 55

Magnesium	2.2	10.2	Very Good
Barium Nitrate	5.8		
Polyvinyl Chloride	1.8		

Formula No. 56

Sulfur	1.8	62	Black smoke of heavy volume
Barium Nitrate	5.8		
Polyvinyl Chloride	2.2		

Formula No. 57

Sulfur	1.0	13.4	Yellow with tinge of Green
Magnesium	.8		
Barium Nitrate	5.8		
Polyvinyl Chloride	2.2		

Formula No. 58

Charcoal	1.5	39	Yellow, last 3 sec. Green
Barium Nitrate	5.8		
Polyvinyl Chloride	1.5	43	Yellow, last 3 sec. Green
Magnesium	1.0		

Formula No. 59

Charcoal	1.5	46.6	Yellow Flare
Barium Nitrate	11.6		
Polyvinyl Chloride	1.5		
Magnesium	1.0		

Formula No. 60

Magnesium	1.8	8.2	Very Good
Barium Nitrate	5.8		
Mercuric Chloride	2.2		

Formula 61

	Pts.	B.T.	Degree of Green Color
Charcoal	.95	27	Fair
Barium Nitrate	7.40		
Hexachlorethane	.95		
Magnesium	.65		

Formula No. 62

Charcoal	1.00	27.8	Yellow with flashes of Green
Barium Nitrate	7.00		
Hexachlorethane	1.30		
Magnesium	.65		

Formula No. 63

Magnesium	1.00	10.0	Very Good
Barium Nitrate	7.00		
Polyvinyl Chloride	1.50		

Formula No. 64

Charcoal	1.0	27.2	Yellow with tinges of Green
Barium Nitrate	7.0		
Polyvinyl Chloride	1.3		
Magnesium	.65		

Formula No. 65

Magnesium	.75	18	Very Good
Barium Nitrate	7.00		
Polyvinyl Chloride	1.75		

Formula No. 66

Magnesium	.75	18.8	Yellow with tinge of Green
Barium Nitrate	6.50		
Polyvinyl Chloride	2.25		

Formula No. 67

Charcoal	.95	35.6	Yellowish-white light
Barium Nitrate	7.00		
Tellurium Oxide	.40		
Polyvinyl Chloride	.95		
Magnesium	.65		

Formula No. 68

Barium Nitrate	8.00		Dud
Hexachlorbenzene	2.00		

Formula No. 69

	Pts.	B.T.	Degree of Green Color
Barium Nitrate	8.0		Dud
Hexachlorbenzene	2.0		

Formula No. 70

Barium Nitrate	5.8		Dud
Polyvinyl Chloride	2.2		

Formula No. 71

Magnesium	1.2	27	Fair
Boron	.6		
Barium Nitrate	5.8		
Polyvinyl Chloride	2.2		

Formula No. 72

Boron	.95	25	Very Good
Barium Nitrate	7.40	15.6	Very Good
Polyvinyl Chloride	.95	14.8	Very Good
Magnesium	.65		

Formula No. 73

Magnesium	.50	22.8	Very Good
Boron	.25	26.2	Fair
Barium Nitrate	7.00		
Polyvinyl Chloride	1.75		

Formula No. 74

Boron	1.0	14.2	Very Good
Barium Nitrate	7.3		
Polyvinyl Chloride	1.0		
Magnesium	.7		

Formula No. 75

Boron	.75	20.0	Fair
Barium Nitrate	7.00		
Polyvinyl Chloride	1.75		

Formula No. 76

Boron	1.0	70.0	Yellow Flame
Barium Nitrate	6.5		
Polyvinyl Chloride	2.0		

Formula No. 77

	Pts.	B.T.	Degree of Green Color
Boron	.95	15.5	Very Good
Barium Nitrate	7.40		
Polyvinyl Chloride	.95		

Formula No. 78

Boron	1.50	17.8	Very Good
Barium Nitrate	7.30		
Polyvinyl Chloride	1.00		
Magnesium	.20		

Formula No. 79

Boron	1.00	40.0	Good
Barium Nitrate	7.50		
Polyvinyl Chloride	1.00		

Formula No. 80

Boron	1.50	29.4	Good, at times
Barium Nitrate	7.50		Very Good
Polyvinyl Chloride	1.00		

III. By means of the optical pyrometer the burning temperqtures were taken on the following formulas using 9.8 gms. of composition loosely poured in 3/4" x 4" steel tubes:

Formula No.	Green Color	Burning Time (Seconds)	Burning Temperature (Centigrade)
48	Tinge	18.8	1355
28-2	Very Good	10.8	1310
56	Very Good	10.2	1310
18	Very Good	9	1290
55	Very Good	11	1290
13	Very Good	No Time	1285
28	Very Good	15	1285
36	Good	No Time	1262
45	Very Good	13.8	1242
36	Fair	10.8	1242
54	Good	20.5	1240
18	Very Good	13	1240
47	Good	9.2	1235
45	Good	16.8	1222
45	Fair	17.8	1180
39	Yellow	12	1160
46	Tinge	22	1145
28	Good	13.2	1120
39	Yellow	28	1045
39	Poor	41.6	990

IV. In an attempt to incorporate a green color into a long burning phosphorus formula the following experiments were performed:

No. 1 - A standard 4 inch phosphorus pellet was placed in a steel tube 6 inches by 1 1/2 inches. A mixture of barium nitrate 5.8 parts - polyvinyl chloride 1.5 parts was poured around the pellet and the pellet ignited. The characteristic color of the phosphorus flame resulted.

No. 2 - A long burning phosphorus formula A-85 was mixed.

A-85	%
Phosphorus	56
Manganese Dioxide	33
Magnesium	3
Calcium Silicide	5
Paraffin Oil	3

Five parts of formula 28 and 5 parts of formula A-85 were intimately mixed and tested for burning characteristics. A white light was obtained.

No. 3 - Barium nitrate and polyvinyl choride were mixed in the following proportions.

Barium Nitrate 5.8 parts
Polyvinyl Chloride 1.5 parts

This formula and formula A-85 were mixed in equal proportions. This mixture emitted a white light when tested.

The Barium Nitrate - Polyvinyl Chloride mixture 2 1/2 parts and formula A-85 7 1/2 parts were mixed and tested. A white light resulted.

Two parts of the Polyvinyl Chloride - Barium Nitrate composition and 8 parts of the formula A-85 were mixed and tested. A white light resulted.

No. 4 - The following formulas were mixed and tested.

	Parts	Burning Time	Color
Phosphorus	3.1	12 sec.	Brilliant White Light
Manganese Dioxide	.9		
Barium Nitrate	3.7		
Magnesium	1.2		
Polyvinyl Chloride	.6		
Copper	.4		
Manganese Dioxide	.9	21.4 sec.	White Light
Barium Sulfate	3.7		
Magnesium	1.2		
Polyvinyl Chloride	.6		
Copper	.4		
Phosphorus	3.1		

No. 5 - The following formulas were mixed and tested with A-85.

	Parts		
Barium Stearate	5.8)		
Polyvinyl Chloride	2.2)	2.5	Dud
A-85		7.5	
Barium Stearate	5.8)		
Polyvinyl Chloride	2.2)	1	Dud
A-85		9	
Barium Sulfate	5)		
Polyvinyl Chloride	5)	5	Dud
A-85		5	
Barium Oxalate	2.5)		
Polyvinyl Chloride	2.5)	2	Dud
A-85		8	
Barium Carbonate	1.5)		
Polyvinyl Chloride	1.5)	1	Dud
A-85		9	

DISCUSSION

Parlon, hexachlorethane and plyvinyl chloride tested in the same formulas No. 13, 18 and 26 respectively demonstrate that of the three organic chlorides, parlon possesses the highest energy content and polyvinyl chloride the lowest. Of the three compounds polyvinyl chloride will produce the longest burning formula. It was noted that parlon produced the most intense green color.

The three component system of magnesium, barium nitrate and polyvinyl chloride seems to show promise for use in green flares of medium burning time. Formulas No. 27, 28 and 65 seem to be the best. The boron, barium nitrate, polyvinyl chloride formulas with, or without magnesium, show promise for longer burners. The boron formulas produced green colors of a greater intensity than those produced with other fuels. Formulas which show particular promise are 72, 73, 74, 77 and 78.

The three and four system flares using barium nitrate as an oxidant show much promise in producing good green colors, eliminating the use of perchlorates and of various chemical modifiers.

The temperature readings obtained with the optical pyrometer indicate that an energy level associated with a temperature ranging from approximately 1100°C to 1355°C is required to produce a green colored flare, with the more intense green colors being produced at approximately 1300°C. Below 1200°C the colors tend to become yellow, at a temperature of 1355°C the colors approach white light.

The phosphorus formulas produced no green colors probably due to the face that the energy level was too high.

Some formulas are listed below which were a by-product of the attempt to secure a green flare and which may be of value in other programs.

Formula No.	Burning Time	Characteristic
15	105 sec.	Yellow flame of low energy
19	72.6 sec.	Yellow tinged with Green
38	75.0	Yellow tinged with Green
76	70.0	Yellow flame
56	62	Black Smoke of heavy volume

List of Chemicals Used:

Fuels
- Magnesium - 80/120 **
  Type III, Gran. 15 RDA 76
  Type III, Gran. 16 RDA 170
- Copper Dust RDA 18
- Gilsonite, Asphaltum JAN-A-356 *
- Wood Flour *
- Charcoal RDA 22
- Dextrine RDA 149
- Sulfur JAN-S-487 Grade D
- Boron RDA - 51
- Phosphorus JAN-P-211 Class B *
- Calcium Silicide JAN-C-324 *

Oxidants
- Barium Nitrate RDA 57
- Potassium Perchlorate RDA 43
- Tellurium Oxide RDA 213
- Manganese Dioxide RDA 46
- Barium Sulfate RDA 148

Chorinating Compounds
- Parlon sieved through No. 30 U.S. Standard Sieve *
- Hexachlorbenzene RDA 98
- Mercuric Chloride RDA 153
- Polyvinyl Chloride RDA 31
- Hexachlorethane JAN-H-235 *

Binders and Inhibiters

Stafoam Plastics
Barium Stearate RDA 4
Stearic Acid (Neofat) *
Barium Oxalate, Fisher Reagent Cat. #A220
Laminac 4110
Barium Carbonate RDA 56
Paraffin Oil, Fisher #O-119

* Procured from Ordnance

** This magnesium was used by Ordnance in the phosphorus formulas and was u[illegible] in all the flare formulas unless otherwise noted.

RECOMMENDATIONS

Many of the green flare formulas, notably those containing Boron as a fuel, may be of value in future flare programs and should be given further tests for efficiency of performance.

Some of the yellow flares may also be of value as well as the black smoke containing sulfur, although sulfur in the presence of an oxidizer may present proble s of safety.

At the time these experiments were accomplished, there were no means available for measuring color value. Visual determinations of color values are often misleading. It is recommended that any future test experiments of this nature should be accomplished with the electronic color and light meter which would record the true color and its intensity.

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13. ABSTRACT

The Chemical Laboratory Branch was given the task of developing improved colored flares, which would burn longer than the formula currently in use.

Eighty green flare producing formulas were mixed and tested for burning time and quality of flame. Burning temperatures measured on twelve formulas containing barium indicate that an energy level associated with a temperature ranging from approximately 1100°C to 1355°C is required to produce a green color, with the more intense colors being produced at approximately 1300°C. Below the above minimum temperature the flames were yellow, above the maximum the colors approached white light.

The most promising formulas developed consisted of an efficient three component system containing boron, barium nitrate and polyvinyl chloride.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Green Flares						
Pyrotechnic Compositions						
Flame temperatures						
Temperature						
Pyrometer						

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25 Sep 1959 16p
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3. Green Glares
4. Pyrotechnic Compositions
5. Flare Temperatures
6. Temperature
7. Pyrometer
I. Carl Armour

Eighty green flare producing formulas were mixed and tested for burning time and quality of flame.

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